Driver Behavior at Highway-Rail Grade Crossing Using NDS and Driving Simulators

2017 Grade Crossing Research Needs Workshop

St. Louis, Missouri

Rail Transportation Program

Michigan Tech Transportation Institute • Michigan Technological University

Michigan Technological University

Outline

- Project 1: In-Vehicle Auditory Alerts (IVAA) – Summary
  - Warning types
  - What type of warning works best?
  - Results
- Project 2: Driver Behavior at Highway-Rail Grade Crossings Using NDS Data and Driving Simulators
  - Description of Naturalistic Driver Study (NDS) database
  - Driver compliance behavior
  - Crossing selections
  - Project progress – NDS analysis
  - Project progress – Simulator research
  - Next steps

In-Vehicle Alerts; How to Warn Drivers?

Stimuli

31 novel auditory cues

- **9 Earcons (Beeps)**
  - Varied in pitch, pulse rate, wave shape, etc.
- **6 Auditory Icons (train sounds)**
  - Train horns, “track” sounds, warning bells, etc.
- **16 Verbal messages**
  - 2 Genders (M, F)
  - 2 Voice types (Human, TTS)
  - 4 words (Alert, Caution, Danger, Warning)

Subjective Measurements

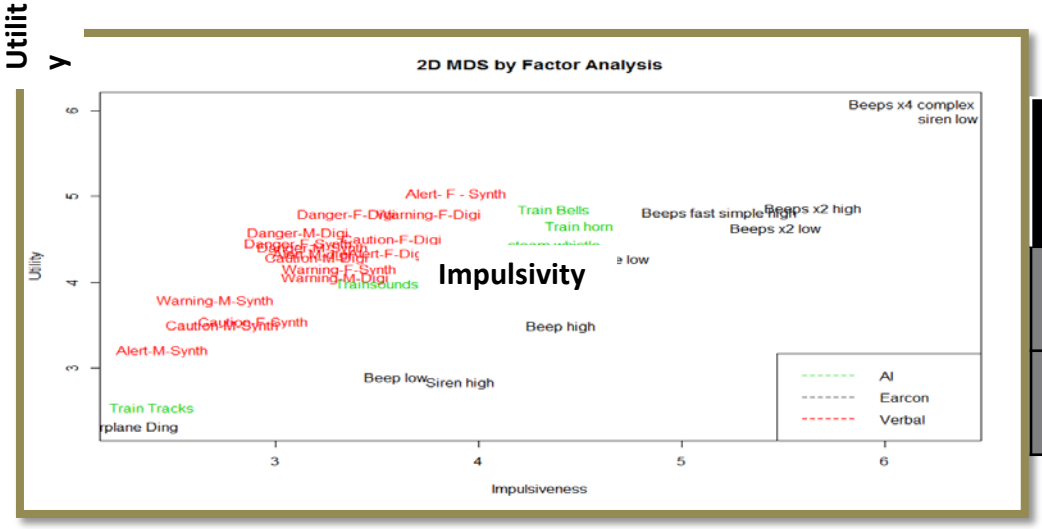
7 psychological dimensions

- Likert scale 1-7
  - Overall Appropriateness
  - Urgency
  - Meaning
  - Discriminability
  - Annoyance
  - Startle effect
  - Natural-In-Car

Baldwin & Lewis, 2014

Analysis of Alternatives

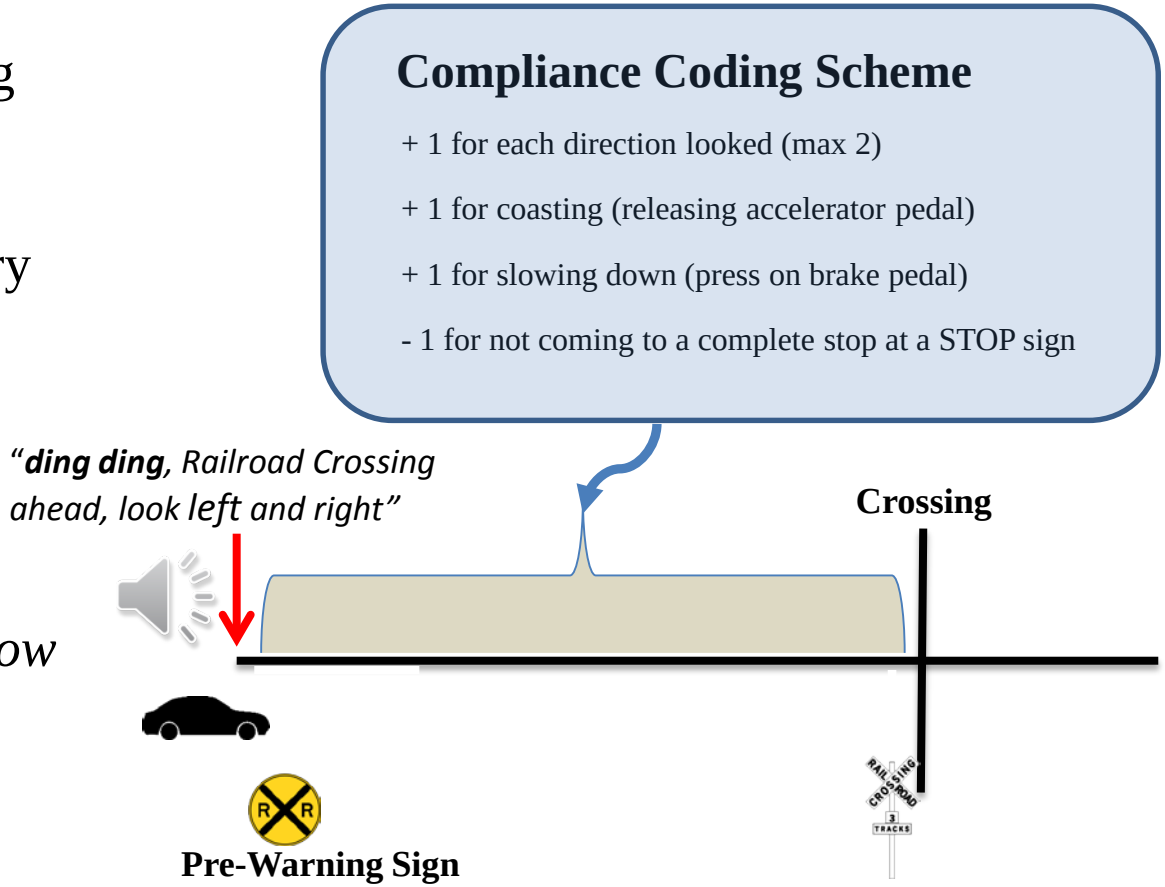
- Principal Component Analysis suggested two main factors (95% of variance explained across all 7 dimensions)
  - **"Utility"** – meaning & natural & urgency
  - "**Impulsivity"** – annoying & startle
- Verbal messages more utility, but Earcons more impulsive
- Auditory Icons somewhere in the middle
- Technique also helped identify the acoustic features relevant for embedding urgency into Earcons.



Perceived urgency	Wave Shape	Number of beeps	Cycle rate	Pitch
High	Saw	Multiple	> 3 per second	> 2000 hz
Low	Sine	Single	< 2 per second	< 1500 hz

Evaluation of System Performance

- **Auditory warning of approaching crossing**
  - Requires GPS + crossing location database
  - No vehicle-train communication necessary (no approaching train warnings)
  - Increase saliency, especially at passive crossings
  - Remind drivers to and *how to* comply



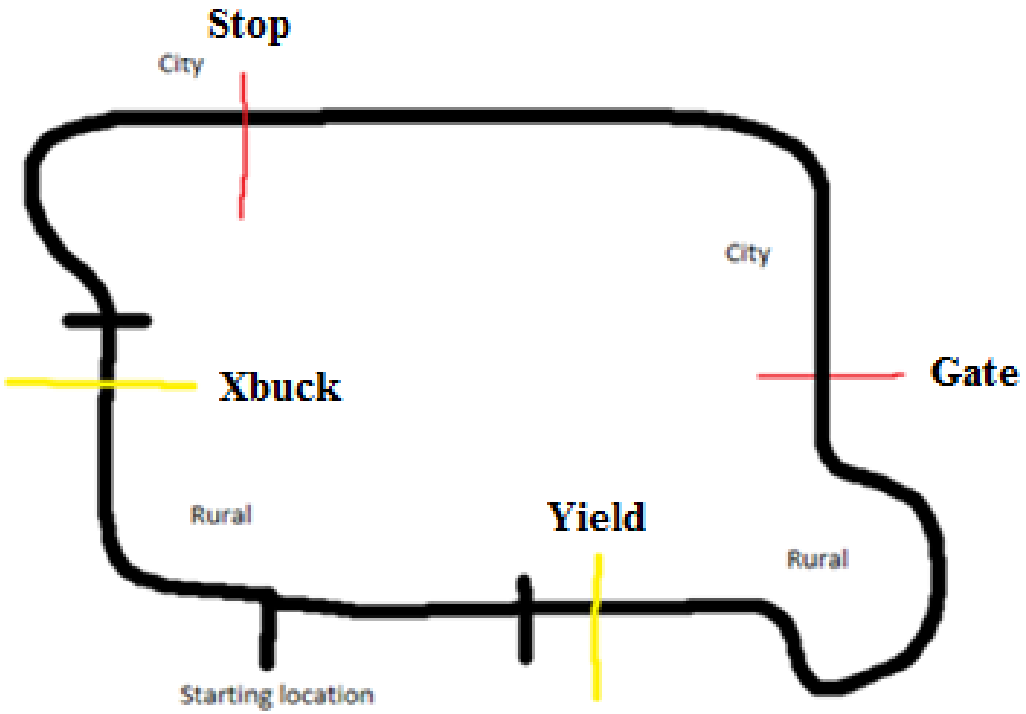
Scenario Design

Two "tracks" per driver

- (~22 minutes each)
- One track with, one without IVAAs

One "track" = 3 laps around scenario

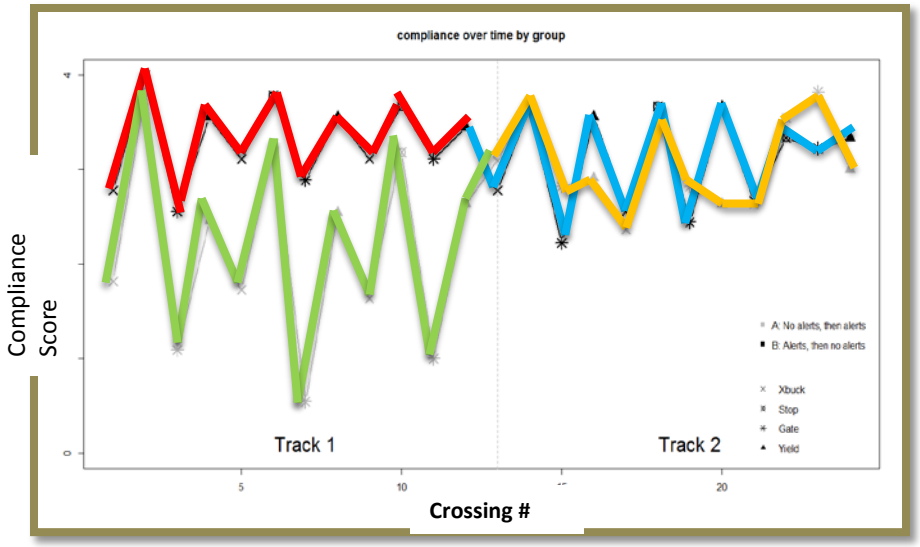
- Each lap contains 4 crossings, 1 of each sign type
- Total of **24 observations per participant**

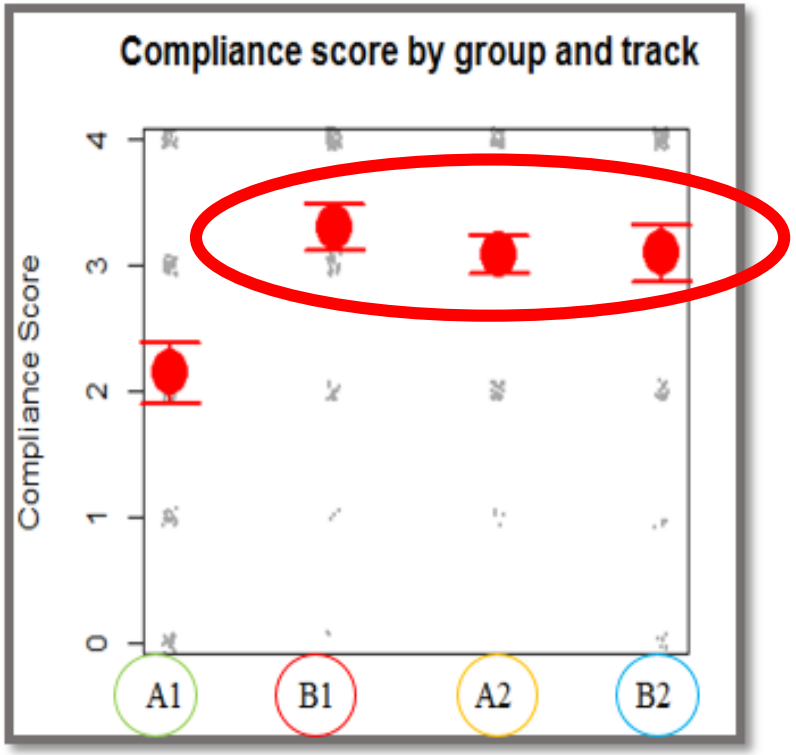


Train present at 23rd crossing (gate)

Compliance Results

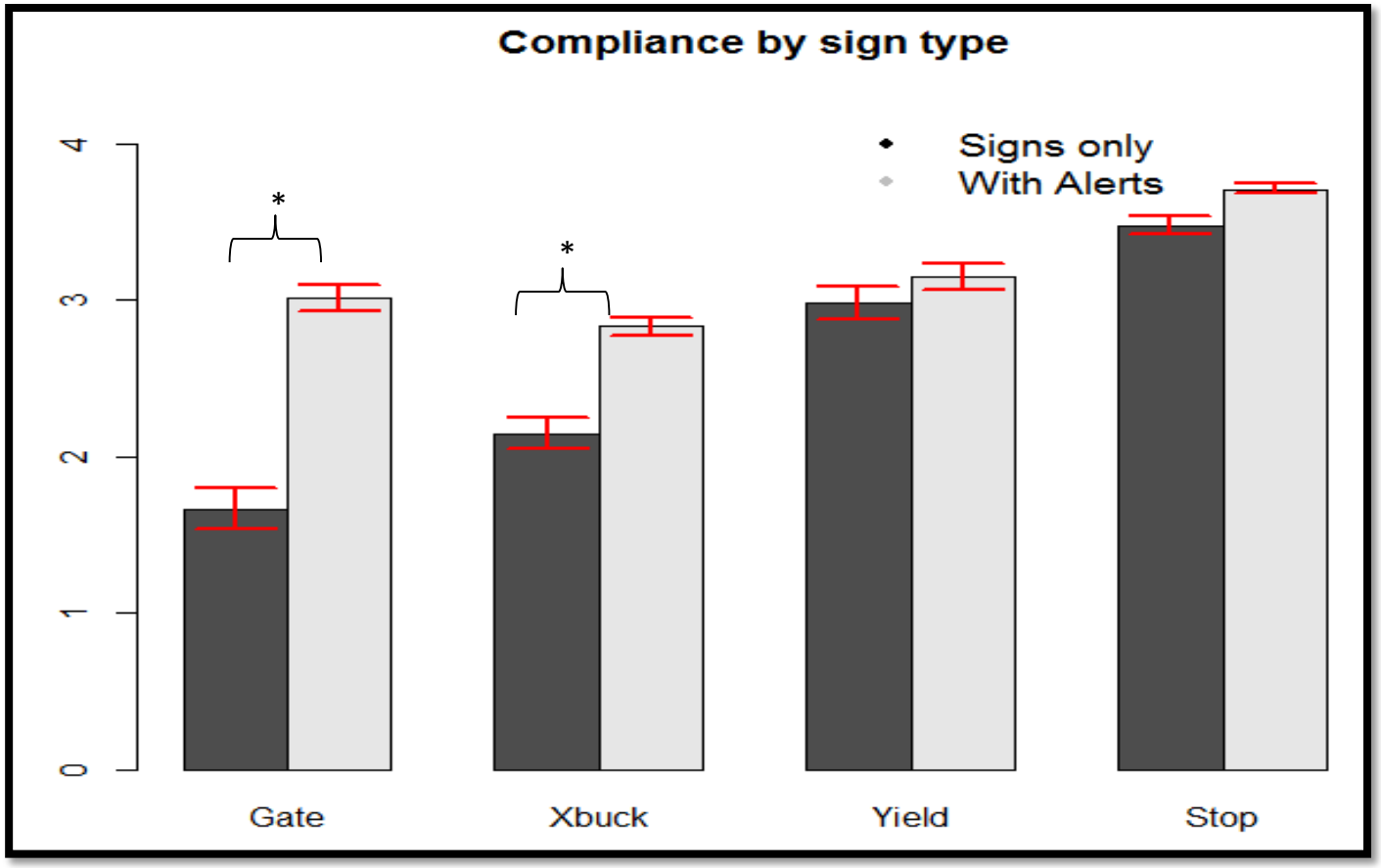
- Increased compliance through auditory alerts
  - B1 = B2 = A2 > A1





- A1, Start with no IVAA
- A2, Add IVAA
- B1, Start with IVAA
- B2, Finish with no IVAA

Gated Crossings Show Greatest Improvement



***Statistically Significant**

NDS/Simulator Project
Description and Goals

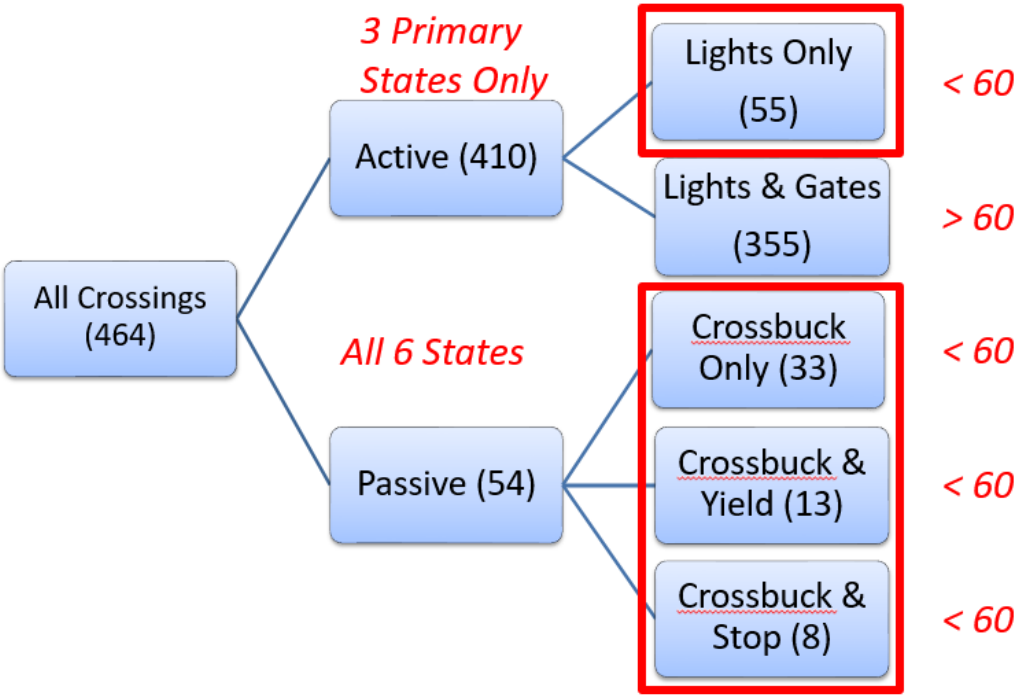
- Schedule: September, 2016 – August, 2018
- Integrate "*Naturalistic Driver Study (NDS)*" and "*Driver Simulator*" research to better understand driver behavior at highway-rail grade crossings
- 94 % of all accidents are caused by "human behavior"
  - Even risky behavior rarely leads to an accident
- The goal is to understand the driver behavior
  - CURRENT: Evaluate effectiveness of current traffic warning/control devices
  - FUTURE: Suggest improvements for future system improvements

SHRP2-Naturalistic Driving Study

- Naturalistic driving data
  - Data are live recorded in-vehicle
  - Behavior expected to be very similar to the natural environment
  - Expensive and difficult to set up
- SHRP2-NDS
  - Data collected between 2011 and 2013
  - 3,500 Vehicles in 6 Regions: FL, IN, NY, NC, PA, WA
  - More than five million trips and over 1,000 crossings involved
  - Data used to analyze driver behavior at grade crossings, ***primarily in non-accident situations***

Crossing selection from the NDS

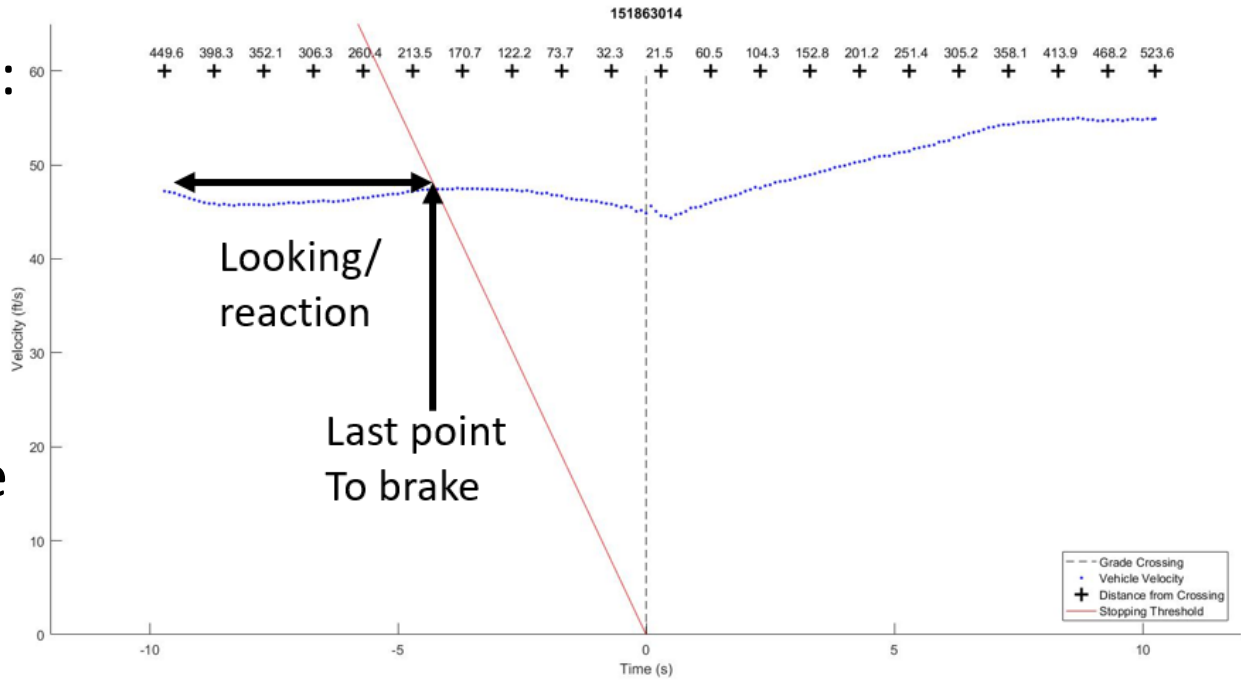
STATE	CROSSINGS IN NDS
Florida	295
Indiana	104
New York	181
North Carolina	168
Pennsylvania	61
Washington	208
TOTAL	**1017**



- The type of traffic control devices verified/corrected with Google Maps
- Three primary main states of interest: Florida, Indiana, New York (to allow contrast in environment conditions)
- GOAL: Statistically significant number of crossings in each category
  - Most of the crossings in the study were active with lights and gates

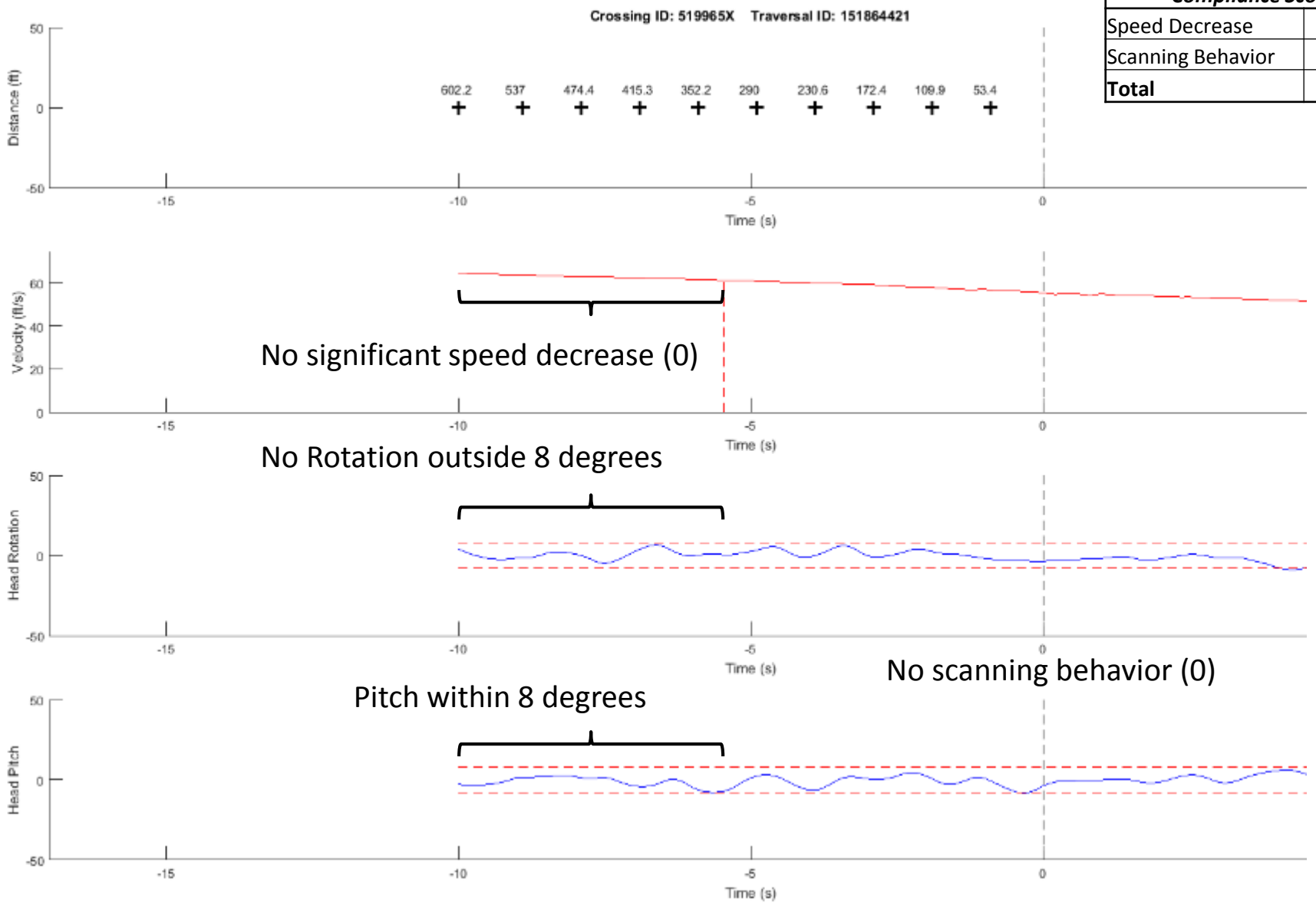
Compliance Score

- Compliance based on:
  - Scanning behavior (2 points)
  - Speed adjustment/ braking (1 point)
- What's needed to see the train?
  - 8 degree radius threshold around origin for looking at road – (Ahlstrom, Victor, Wege, Steinmetz, 2012)
- Timing of actions vs. compliance
  - Timing of head rotation
  - Timing of speed reduction/braking (if applicable)

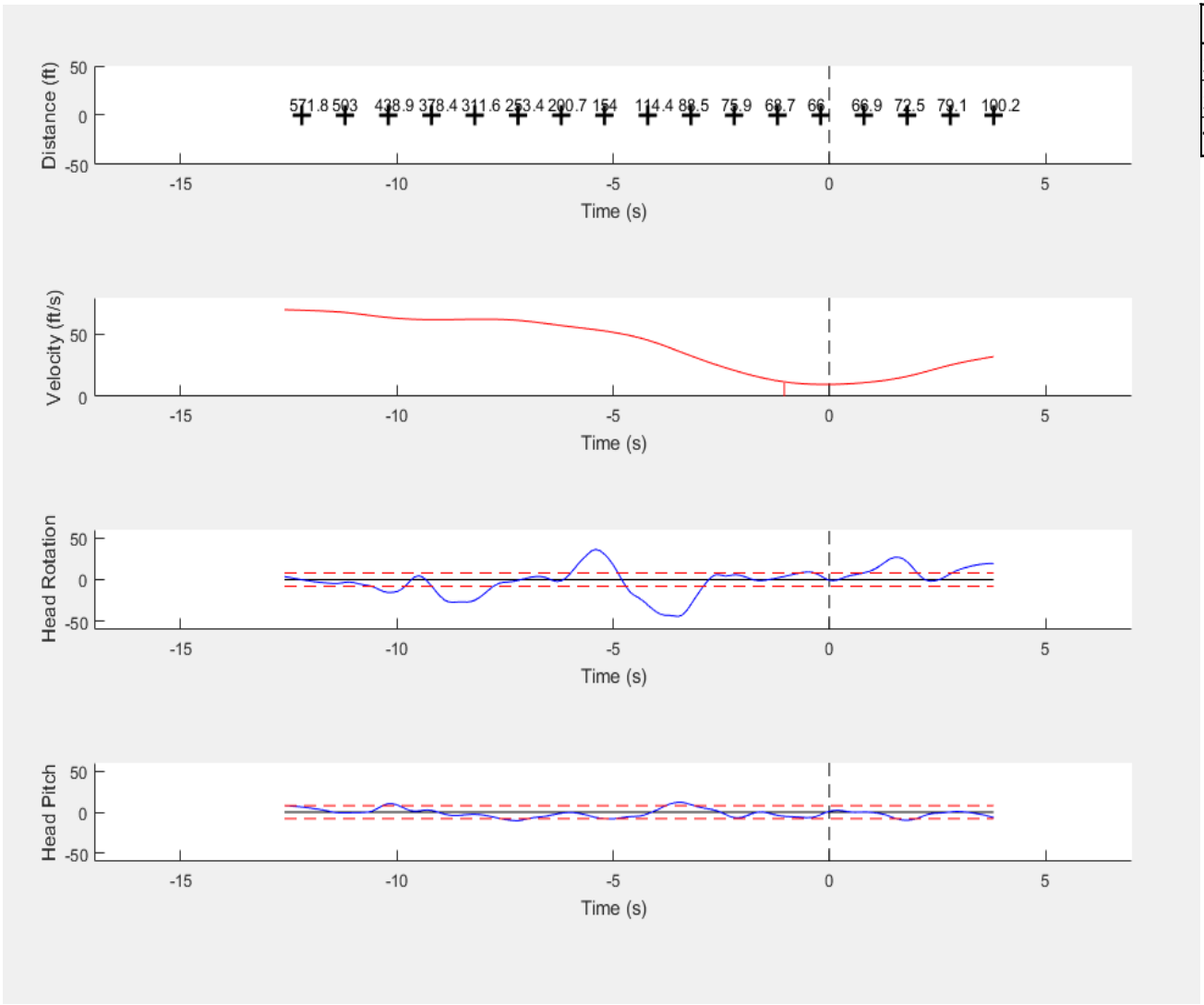


Compliance Scoring – Example 1

Compliance Score	
Speed Decrease	0
Scanning Behavior	0
Total	0



Compliance Scoring – Example 2



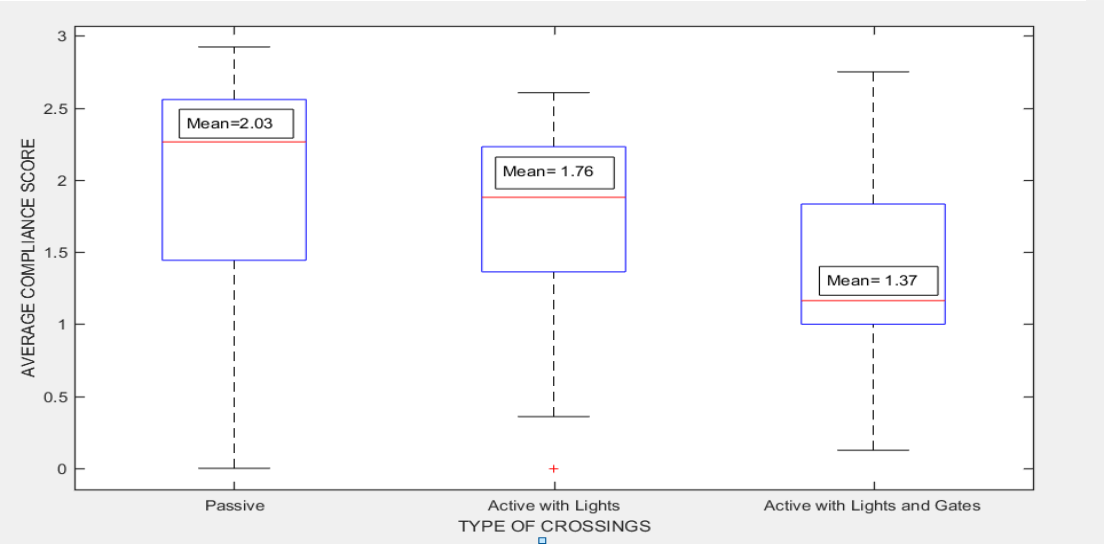
Compliance Score	
Speed Decrease	+1
Scanning Behavior	+2
Total	+3

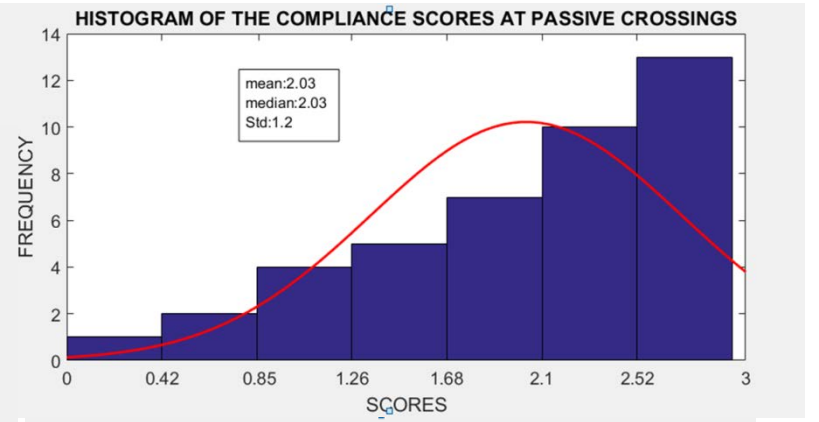
Evaluation of compliance score

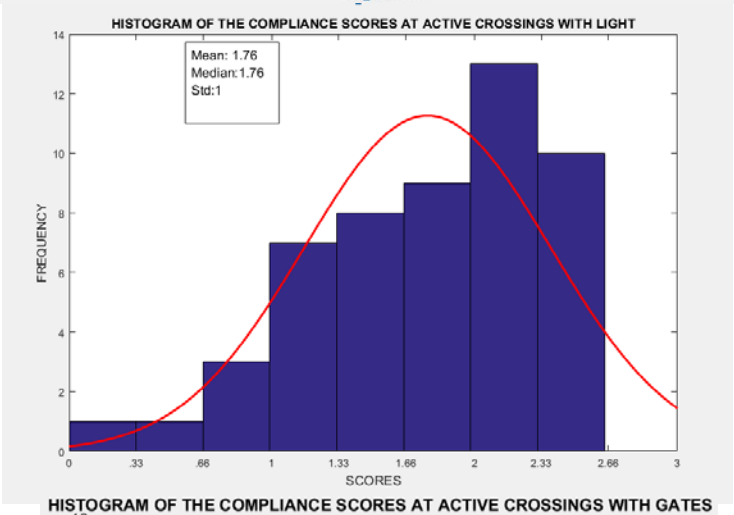
Evaluation of compliance score

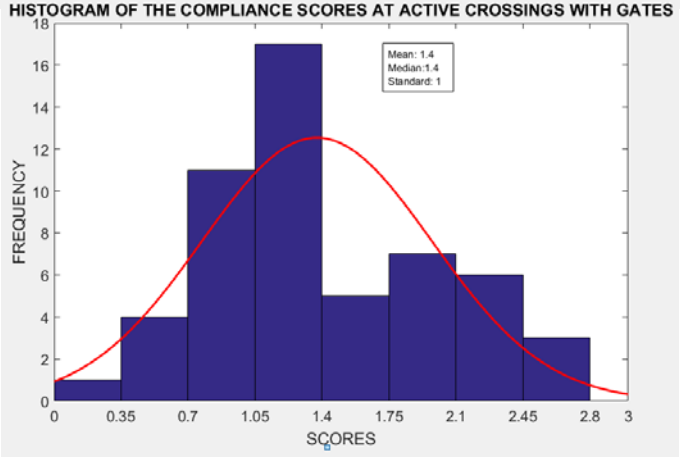
- Compliance scores distribution analysis
- Over 5,000 traversals have been processed to date
- Comparison and correlation analysis based on average compliance scores per cluster
- Clusters are based on :
  - Traffic control devices (passive, active w/ lights, active w/ lights&gates)
  - Angle of the crossing
  - Total trains per day
  - Highway maximum speed

Scores - Crossing Type









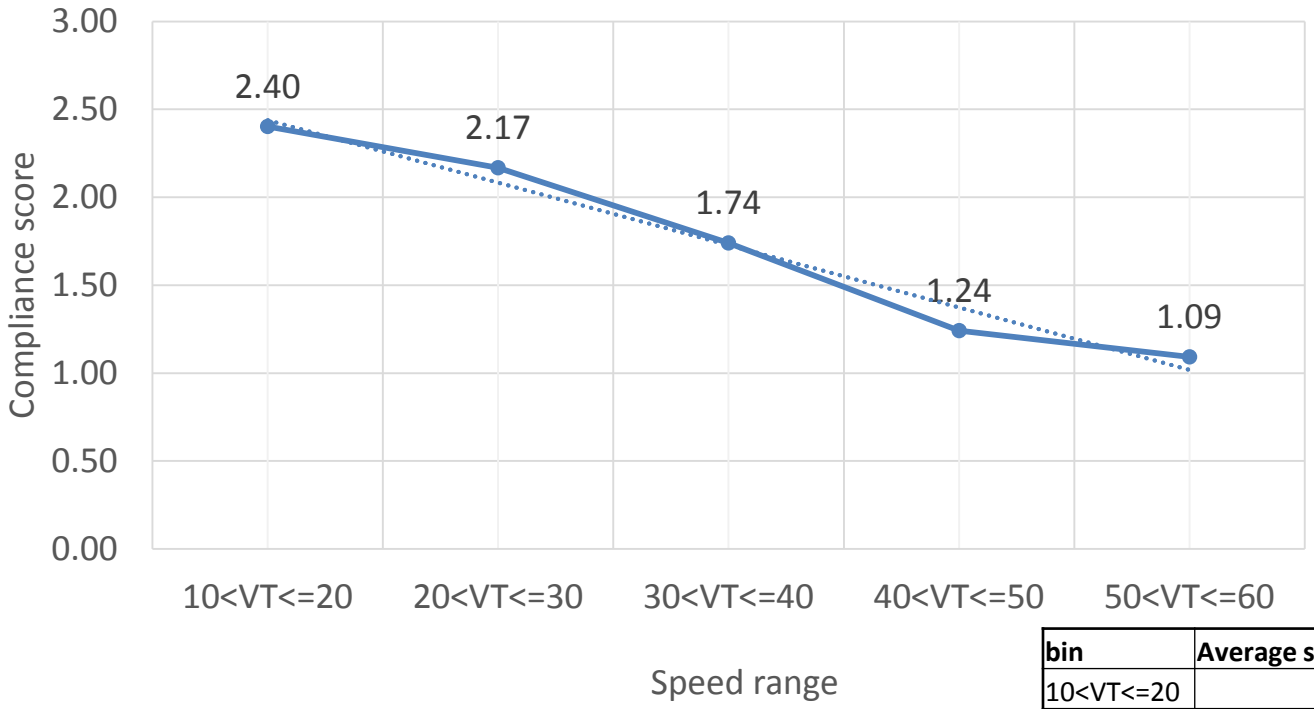
- 2 sample t-test used to verify statistical difference between categories

Where do Drivers Fall Short?

COMPLIANCE ANALYSIS PER BEHAVIOR			
TYPES OF CROSSINGS	**SCANNING SCORE (%)**	**SPEED REDUCTION SCORE (%)**	**OVERALL COMPLIANCE (%)**
Passive	66%	71%	68%
Active with Lights only	57%	63%	59%
Active with Lights and Gates	45%	44%	46%

- The scanning vs. speed reduction behavior offers similar trending with all main TCDs
- Standard deviations are large

Compliance Score Vs Highway Speed



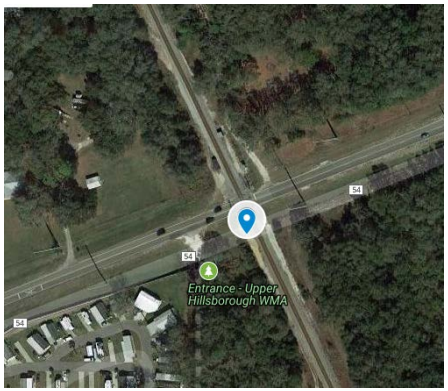
bin	Average score	std	current n	required n
10<VT<=20	2.40	0.55	6	37
20<VT<=30	2.17	0.42	38	21
30<VT<=40	1.74	0.54	39	34
40<VT<=50	1.24	0.53	37	34
50<VT<=60	1.09	0.72	16	62

- Investigate compliance score variation on trends found to “increase risk of accidents”
- Percentage of gated crossings increases as highway speed increases
- More data are needed in some of the clusters

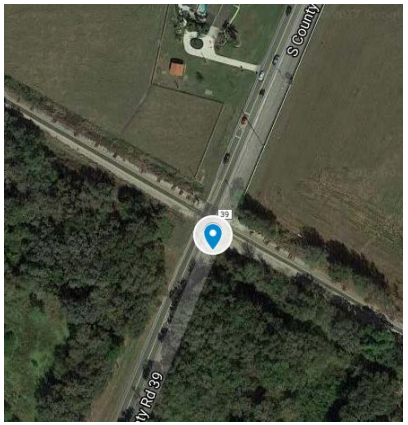
Phase II - Driving Simulator Research

- GOAL: Investigate “simulated” behavior vs. “NDS behavior”
- Will focus initially on existing crossings that are easy to model in simulator using as much of the existing tiles as possible
- Inclusion of crossings based on tiles from past research
  - All are close to right angle crossings (90 degrees)
  - There are four main configuration types:

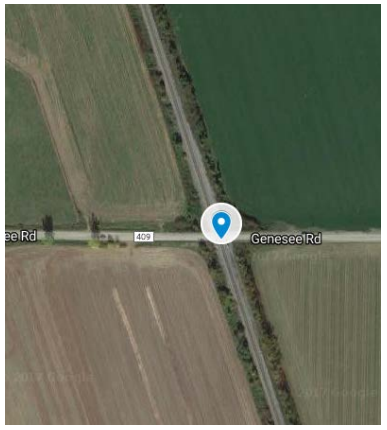
Fully blocked view and no intersection nearby



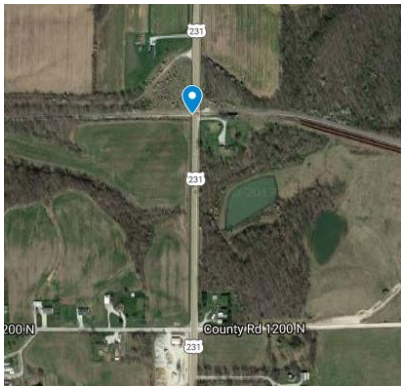
Partially blocked view & no intersection nearby



Clear view and no intersection nearby



Clear view with intersection nearby

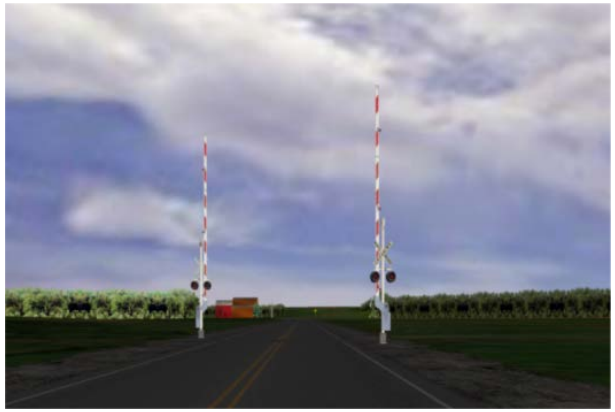


Conclusions (to Date)

- In-Vehicle Auditory Alerts (IVAAs) offer an intriguing new way to alert drivers on approach to crossings
  - Simulator results show clear improvement in driver compliance
- SHRP2-NDS database offers unique opportunity for large scale investigation of drivers behavior at crossings
  - Drivers are more compliant at passive crossings than active
  - Initial results with other parameters are interesting, but not conclusive

Future Research

- Compliance score improvements
- Trends and correlation analysis with larger data samples
- Driver reaction to rough crossings
- Combined effect of different parameters
- Demographics (age and gender)
- Compare simulator results with NDS



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Thank You!